I. C. 6498

SEPTEMBER. 1931

DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
SCOTT TURNER, DIRECTOR

INFORMATION CIRCULAR

METHOD AND COST OF QUARRYING LIMESTONE AND SHALE AT THE QUARRY OF THE TRINITY PORTLAND CEMENT CO., DALLAS, TEX.

RECEIVED
OCT 15
O. S. U.

BY

J. WILLIAM GANSER

I.C.6498
September, 1931.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

METHOD AND COST OF QUARRYING LIMESTONE AND SHALE AT THE QUARRY OF THE TRINITY PORTLAND CEMENT CO., DALLAS, TEXAS[1]

By J. William Ganser[2]

INTRODUCTION

This paper is one of a series being prepared by the U. S. Bureau of Mines describing mining and milling methods and costs at cement-plant quarries throughout the United States. These papers are designed to disseminate technical information regarding the methods used. The cost tabulations represent local operating expenditures only and not total production costs. It is recognized that publication of total production costs might in many instances cause embarrassment to individual producers as well as to the industry as a whole. On the other hand, operating costs are essential to the technical discussion and study of the methods employed. The attention of the reader is specifically called to this differentiation in order that no misunderstanding of the scope of the cost tabulations shall ensue.

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of Fred Burkett, civil engineer, and F. O. Londrey, chief clerk, of the Trinity Portland Cement Co., for assistance in preparation of this paper. "The Geology of Dallas County, 1918," Bulletin 1818, Texas Geological Survey, Austin, Tex., by E. W. Shuler, was also freely consulted.

HISTORY

In 1908 the Southwestern Portland Cement Co. broke ground for its plant on a site 7 miles west of Dallas, on the western outcrop of the limestone belt. The mill was built by W. H. L. McCourtie and W. F. Cowham, and the first cement was manufactured during July, 1909.

The plant was originally designed for an output of 1,500 barrels per day but not many years passed before demand exceeded this capacity and it was then increased to 3,500 barrels.

The company operated under the name of the Southwestern States Portland Cement Co. until 1914 when the name was changed to the Trinity Portland Cement Co.

The quarry, situated about a half mile east of the mill at that time showed a limestone outcrop 20 to 25 feet high, much of which was decomposed due to weathering, but the present quarry face is 35 to 40 feet high.

---

[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6498."

[2] One of the consulting engineers, U. S. Bureau of Mines, and chief chemist, Trinity Portland Cement Co.

The shale necessary in the manufacture of cement is obtained directly under the lime rock.

GEOLOGY

The limestone which we quarry, commonly called "white rock," is an outstanding topographic feature of the country in that it is a well-defined formation developed in an indurated chalk and marl-limestone formation. This formation is about 10 miles wide, running east of north and south of west, and is known as the Austin chalk, which is of the Upper Cretaceous age.

Although the formation is called Austin chalk, there are only a few layers properly termed "chalk." The white rock is much softer than the blue rock which is also present in large quantity.

The Eagle Ford shales which lie beneath the Austin chalk have an average thickness of about 500 feet. They are generally soft, weather rapidly, and are predominantly blue or bluish-black. However, their upper layer is a 6-inch seam of exceedingly hard conglomerate made up of shells and sand. Below this seam there are many blue lime concretions of various sizes which obtain their color from carbonaceous material.

The overburden, a dark brown soil becoming very waxy when wet, is not stripped. It varies in thickness from a thin layer to 8 or 10 inches, except for occasional pockets sometimes 2 feet in depth.

PHYSICAL CHARACTERISTICS OF STONE

The Austin chalk disintegrates quite rapidly when exposed to the weather, and the organic matter in it is leached and carried away. As a result the first 100 to 150 feet of the outcropping limestone is cream-colored. This stone is easily broken with explosives and crushed with little difficulty. However, the quarry as it is to-day consists mostly of a bluish gray stone from which the organic matter has not been leached. The top 6 or 8 feet of the quarry face is creamy white, and wherever there is a fissure the creamy-white rock is from 4 to 12 inches wide along it.

Characteristic of the Austin chalk are the large number of fault planes. The dip of these fault planes is generally about 45°, and the strike is northeast and southwest. We had an excellent opportunity to accurately determine these dips because of the smooth quarry face left by an Adel excavator which was at one time used to get out the rock. This excavator was an electrically operated machine with a bucket elevator, containing tool-steel cutters between every second bucket, the cutters being forced against the face of the rock and shaving off the limestone, which was picked up by the buckets and elevated to a bin and from there loaded into cars. The cuttings of this machine ranged from fine powder to pieces 2 or 3 inches long and about 1 inch in diameter. Had the excavator worked satisfactorily it would have been unnecessary to operate a preliminary crusher; but unfortunately the rock was too hard and the cost of repairing the machine became prohibitive, so its use was discontinued.

Figure 1 shows a cross section of the Austin chalk, the beds of which have a general dip varying from 40 to 100 feet per mile, and an average dip of 50 to 60 feet. The

Digitized by Google Original from THE OHIO STATE UNIVERSITY

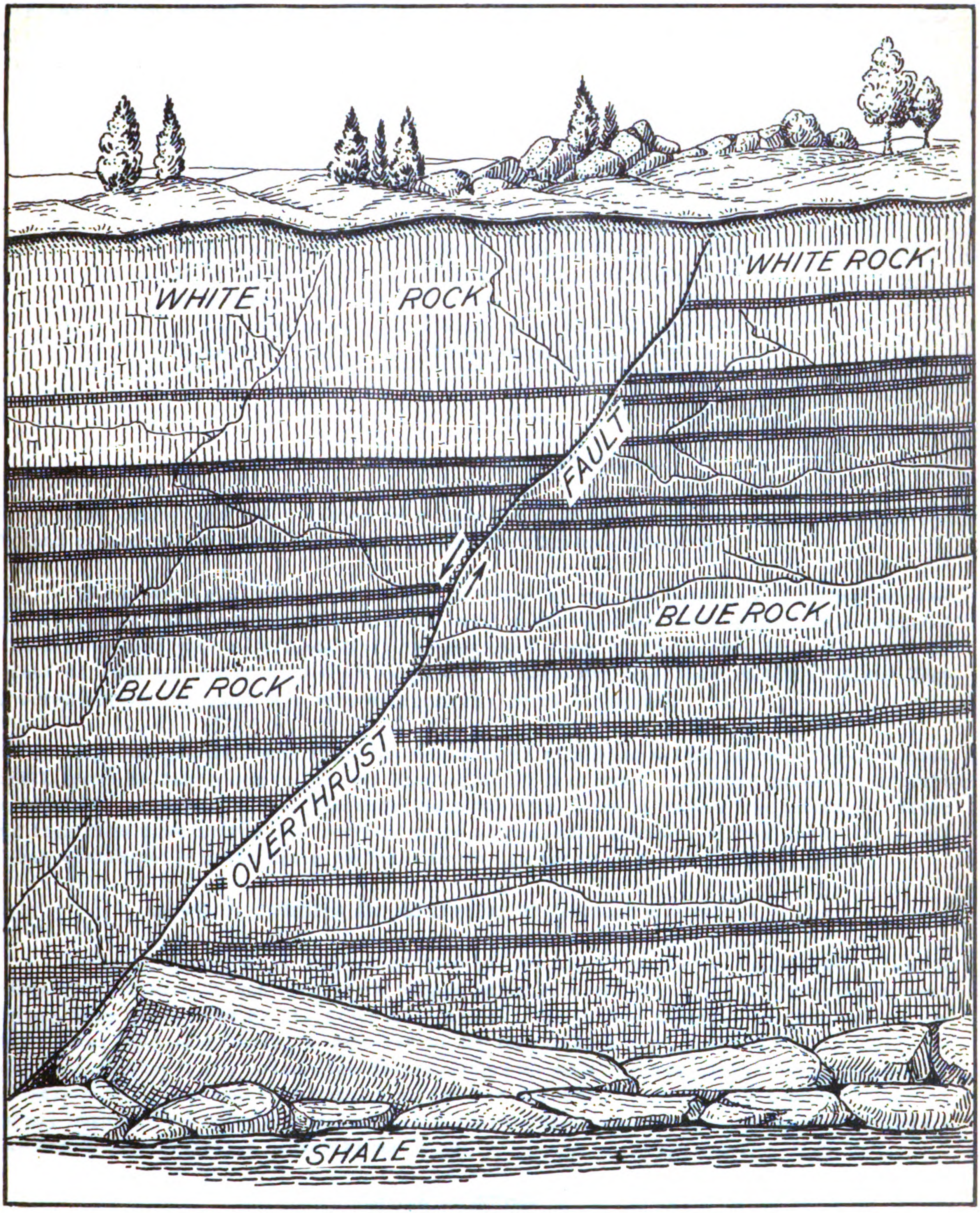

Figure 1.—Cross section of Austin Chalk

chalky layers are separated by thin layers of hard marly rock which on exposure to the weather disintegrate and are etched back more rapidly than the massive chalks, giving the quarry face a rippled or ledgy appearance.

The surface rock weathers into a productive, brownish-black soil.

Chemical composition of rock and shale, per cent

	SiO_2	Fe_2O_3	Al_2O_3	$CaCO_3$	$MgCO_3$
Blue chalk	6.60	1.57	3.13	85.11	1.05
White rock	3.20	1.27	1.61	92.49	.95
Hard marly rock, easily disintegrated	16.82	2.82	10.60	65.20	3.74
Eagle Ford shale	51.90	4.86	19.04	10.17	2.15

METHOD OF PROSPECTING AND EXPLORATION

The quarry was first opened on a face about 20 feet high. The rock was drilled with hand augers and the drillings were sampled for chemical analysis.

Carpenters' nut augers which were used for boring the rock were 2 inches in diameter, 19 inches long and had the ½-inch threaded point removed. The augers were tempered and then sharpened with a file whenever the operator thought they needed it. About 400 to 500 feet of rock was bored before the auger was retempered, and about 5,000 to 6,000 feet were bored before the auger was worn sufficiently to be discarded.

One man operated each auger and was able by attaching 4-foot joints of ¾-inch pipe to drill about 75 feet a day and to put down holes 30 feet deep. This was quite a difficult task as it was necessary to pull the auger many times in order to remove the cuttings. After using this laborious method for several years a homemade, gasoline-driven churn drill was put into operation, but was later replaced by an electrically driven cyclone drill.

METHOD OF SAMPLING AND ESTIMATION OF TONNAGES AND VALUES

None of the rock is sampled at the quarry, as it would be impossible to get a representative sample, but a continuous sample is taken after the lime rock containing some shale has been pulverized by the Krupp ball mills. The ground material is conveyed to one of four steel bins each having a capacity of 84 tons. When one of these bins is full the sample is collected for a quick lime determination in order to ascertain the percentage of shale necessary to be added to make a proper raw mixture. A composite sample of all of these bin samples is completely analyzed each month. The shale is only analyzed occasionally, as there is practically no variation in it.

CHOICE OF METHOD

As already stated, overburden is not removed by mixes with the rock and is loaded with it into cars for the crusher.

Open quarrying is the only feasible and most economical method of obtaining the rock. In opening the quarry the operation was simple as the outcrop formed a bluff. Therefore, after shooting the face it was only necessary to head into the rock with a steam shovel with the quarry tracks laid on the Eagle Ford shale along the face.

The quarry face is now 30 to 40 feet high, but it will eventually be 50 to 55 feet high as the surface rises and the base dips away from the face.

The plan of the quarry (fig. 2) shows that the face is now being worked in a fairly straight line, although when the quarry first opened and for many years after it was worked with a circular face.

Drainage has always been a problem. Because of the dip of the quarry floor each cut made by the shovel is lower than the preceding one and often after a rain the shovel stood in water. This water was either pumped out by a motor-driven centrifugal pump with a capacity of 300 gallons per minute or was syphoned by means of steam from the shovel.

Drainage for the present has been provided by ditches dug with an electric shovel. These ditches are much lower than the quarry floor will be for several years.

MINING METHODS

The lime rock, which is used only for Portland cement, is quarried with 1 to 2 feet of shale which lies directly beneath it. This rock and shale, with the additional shale which is quarried separately, amounts to 1,000 to 1,200 tons per day. By quarrying this amount six days a week it is never necessary to run the quarry on Sunday. The cut averages about 30 feet wide and from 30 to 40 feet high. The face now being worked is about 2,000 feet long on land recently purchased and is the farthest from the crushing plant approximately 5,000 feet away.

DRILLING AND BLASTING

Primary drilling is done with a Cyclone churn drill equipped with a 4-inch bit making a 4½-inch hole. This drill is electrically operated and is self-propelled on traction wheels by a 15-hp. variable-speed motor using 550-volt, 25-cycle current. Two men operate this drill, 10 hours a day, and normally drill 180 feet. The cost of drilling labor is 7 cents per foot.

The holes are drilled in two rows, the first 12 feet from the face with holes 10 feet apart, and the second 10 feet back of the first row with holes also 10 feet apart, and staggered 5 feet off center from those in the first row.

The holes vary from 30 to 35 feet deep, and are drilled to the shale. They are loaded so as to shatter the rock enough to pass through a 2½-yard bucket. No rock is loaded from the teeth of the bucket, but often large rocks pass through the bucket and have to be gadded before being dumped into the crusher. Gadding is done with a pointed chisel about 8 inches long, made of 1-inch octagon tool steel. There are many times when this pointed chisel is driven 5 and 6 inches into the rock without splitting it. The only thing then to do is to pull out the gad and drive it into the rock somewhere else.

Original from THE OHIO STATE UNIVERSITY

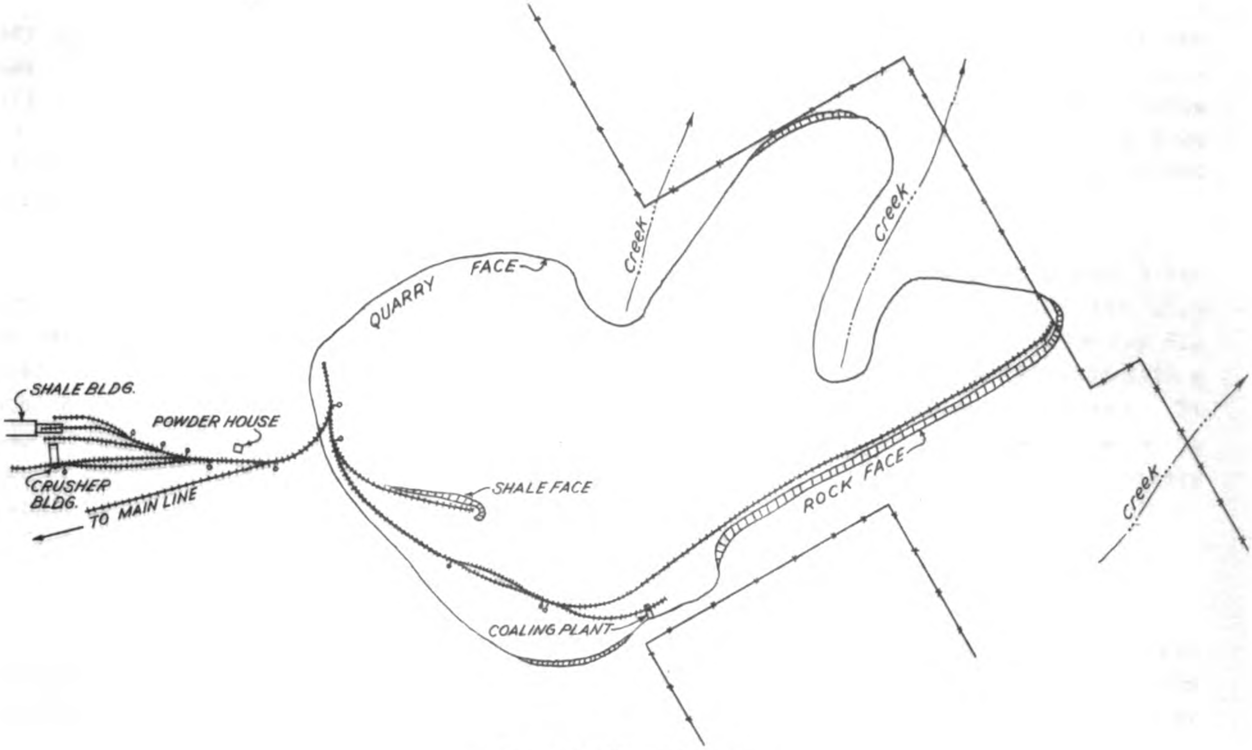

Figure 2.- Track layout

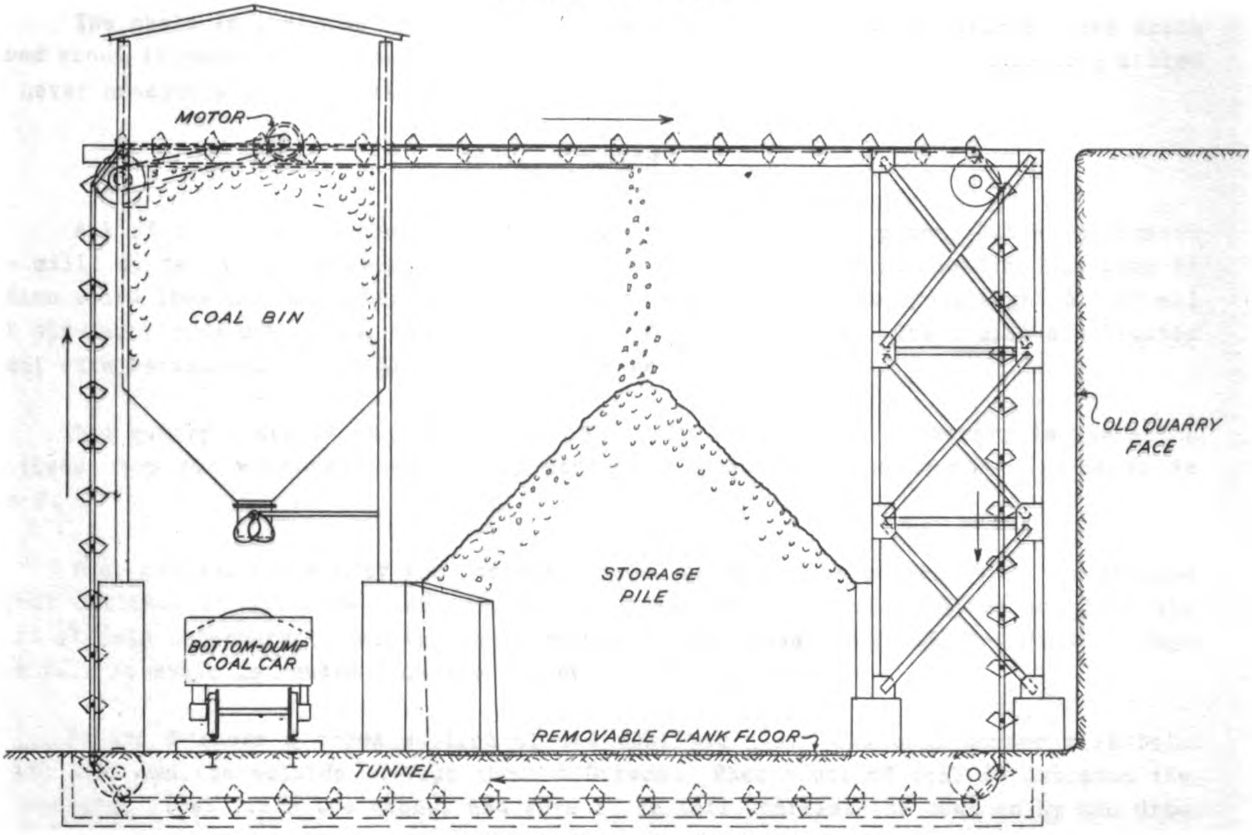

Figure 3.- Quarry Coaling Plant

The usual custom is to shoot 20 to 25 holes simultaneously. When making the primary shots 4 by 8 inch 40-per cent Atlas Giant gelatin dynamite is used, each hole requiring about 50 pounds of the explosive. Cordeau-Bickford is used on all primary shots, set off with a No. 6 detonator. About 80 per cent of the dynamite is placed in the bottom of the holes and the other 20 per cent is placed about one-third of the depth of the hole from the top. The holes are loaded in the usual manner and tamped with dirt by a wooden pole on a rope. It usually takes 10 to 15 men about three hours to load 20 holes.

The primary shooting is done ahead of the shovel; that is, there is always a two or three weeks' supply of rock ready for it. Bowlders that are too large for the rock crusher are not loaded into the cars but are laid aside for secondary shooting. The two men employed to do the secondary shooting bore a hole part way through each bowlder by hand with a 1½-inch carpenter's nut auger welded into a ½-inch pipe with a cross piece at one end. It is only necessary to use one-third to one-half stick of 40-per cent gelatine dynamite to shatter a bowlder sufficiently. Fuses about 36 inches long are used in this secondary blasting.

LOADING

All the lime rock at present is loaded by a No. 70 Marion steam shovel with a 2½-yard dipper. This shovel when bought was of the railroad type but several years ago the wheels and trucks were replaced with caterpillar traction. This change not only saved time in moving the shovel, but it also allowed two men to be dropped from the pit crew.

The shale is quarried by an old No. 60 Marion steam shovel of railroad type which was used about 10 years ago to load lime rock. Since only 10 to 12 feet of shale is quarried it is never necessary to shoot it.

TRANSPORTATION

All of the rock and shale is transported to the crushing plant, which is located at the mill, by two 35-ton Vulcan steam locomotives. One of these locomotives has been in operation since 1909 and the other since 1917. These locomotives each pull eight Oliver and Koppel six-yard, side-dump cars, hauling a load of 65 tons of rock. The trains are limited to eight cars because of grades which run as high as 5 per cent.

The quarry track is standard gage. The only double track necessary is where the locomotives stop for water and where they pass each other near the crusher, as shown in Figure 2.

When hauling shale only four cars are used, as the shale storage will accommodate only four carloads at one time. As only 10 to 12 per cent of shale need be added to the rock, it is only necessary to run the shale shovel at odd times; and when the shale storage is once full no shale is hauled from the quarry for several weeks.

Figure 3 shows a cross section of the coal storage. The coal hopper will hold about 100 tons and the outside storage about 500 tons. When a car of coal is unloaded the bucket elevator first fills the hopper and when it is full, carries the coal on by and discharges it on the outside storage. Coal for the locomotives and the shovels is drawn from the bottom of the hopper.

CRUSHING PLANT

The flow sheet of the crushing plant is given in Figure 4. Coarse crushing is done by a 36 by 60 inch Allis-Chalmers Fairmount roll crusher, belt-driven by a 100-hp. 500-r.p.m. motor. (All motors at the Trinity plant are driven by 3-phase, 25-cycle, 550-volt current.) The capacity of this crusher is 250 tons per hour, but its output is limited by the capacity of the pan conveyor which handles its discharge and of the hammer mill which follows it.

The rock coming from the roll crusher, about 6 to 8 inches in diameter is carried by a short pan conveyor, driven by a 15-hp. 750-r.p.m. motor, to a No. 8 Williams hammer mill belt-driven by a 150-hp., 500-r.p.m. motor.

The discharge from the Williams mill, which is about 1 inch and under in size, is conveyed by a 30-inch rubber belt, driven by a 25-hp., 750-r.p.m. motor, to the rock storage which has a capacity of 8,000 tons. Rock is taken from this storage by a 24 by 32 inch McCaslin bucket conveyor which passes under the storage, through a tunnel, and delivers the rock to two bins which feed two 6 by 70 ft. gas-fired dryers. The conveyor is driven by a 10-hp., 750-r.p.m. motor.

The rock as it comes from the quarry contains 10 to 12 per cent moisture and, passing the Williams mill, has the following screen analysis:

Screen size passed	Per cent
1½ inch	100.00
1 do	90.3
¾ do	78.7
⅜ do	56.0
4 mesh	41.7
8 do	29.6
16 do	22.4
30 do	17.2
50 do	14.9
100 do	11.1

The dryers reduce the moisture content to about 1 per cent by burning 926 cubic feet of natural gas per ton of rock, at a cost of 17.5 cents per 1,000 cubic feet. Figure 5 shows the details of the burner which is made in our shops.

The rock from the two dryers is elevated by a bucket elevator and then conveyed by a screw conveyor to a bin which feeds six No. 8 Krupp ball mills, each belt driven by a 50-hp., 500-r.p.m. motor. The elevator is of the centrifugal-discharge or continuous-bucket type. The buckets are made of 3/16-inch iron and hold about 1 cubic foot each; that is, they are 20 inches wide, 17 inches deep, 12 inches wide at the top and taper to about ½ inch. These buckets are attached to two No. 844 manganese-steel chains. The elevator travels 150 feet per minute, and has a capacity of 60 tons per hour. After being elevated, the rock is conveyed by 16-inch screw conveyors in unlined sheet-iron troughs. The repairs on the screw conveyors are minor, as the Austin chalk is not abrasive but has a soapy feeling. There are many sections of conveyors that have not been replaced for years. Replacements are only necessary when large pieces of scrap iron come from the quarry, and getting into the screw conveyor bend the flights to that they will not propel the rock along the trough.

The Krupp ball mills contain a charge of 4,800 pounds of 5-inch forged steel balls. The liners are manganese plates, none of which have ever had to be replaced from being worn out; the only replacements have been when one occasionally cracked. The wear on the steel balls is about 300 pounds per mill per year. The mills each have a capacity of 7 tons per hour and contain a load of about 800 pounds of limestone; the limestone remaining about 3½ minutes in the mill. The screen analysis of the ball mill discharge is as follows:

Screen size passed, mesh	Per cent
4	100.0
8	99.1
16	94.2
20	82.0
30	69.2
50	61.9
100	56.6

This material is then elevated by the same type of bucket elevator as previously described, and conveyed by screw conveyors, driven by a 25-hp., 750-r.p.m. motor, to four steel bins. These bins, each holding 84 tons, are filled one at a time and are emptied one at a time by a screw conveyor which feeds a bucket elevator driven by a 25-hp., 750-r.p.m. motor. The elevator delivers the ground rock to a bin from which it is drawn and weighed in 6-ton batches. Here the shale is added and the two materials are emptied into a 5 by 22 foot mixing mill, belt-driven by a 50-hp., 500-r.p.m. motor.

From this mixing mill the material is elevated by a 20-inch bucket elevator, speed 150 feet per minute, and conveyed by a 16-inch screw conveyor to 8 bins over the tube mills. This elevator and conveyor are both driven by a 25-hp., 750-r.p.m. motor.

The final pulverizing is accomplished by eight 5 by 22 foot tube mills, each belt-driven by a 150-hp., 500-r.p.m. motor. These mills discharge a "raw mix" with 90 per cent minus 200 mesh. The tube mills are loaded with 25 tons of slugs, 1 by 1½ inch chilled castings, which wear down at the rate of about 2 tons per year. The slugs about half fill the mill. The mill is fed from a hopper-bottom bin by a 6-inch screw conveyor. The speed of this screw conveyor has been determined by experiment so as to regulate the feed to give the required fineness of ground product. The discharge from the tube mills is elevated to five bins, and fed to five kilns, where it is burned at 2,800° F., fused into a clinker, which, when ground with 3 per cent of gysum makes a Portland cement.

The shale is crushed in a dry pan to about ½ inch size and under. This dry pan is a pulverizer commonly used at clay plants and is a horizontal, revolving table, 8 feet in diameter, with sides about 1 foot high. The center 4 feet of the table is of solid steel, and the outer 2 feet is made of cast plates in which are 9/16 by 4 inch slots. Two steel rolls, each weighing 1 ton, crush the shale as it passes between the rolls and the revolving plate. The fines pass through the slots and the coarse particles are pushed back again under the rolls to be crushed. In feeding the dry pan the shale is spouted so that it falls under the rolls. The dry pan is belt-driven by a 50-hp., 500-r.p.m. motor; and the dryer and elevators are driven by two 25-hp. motors, belted in tandem to one pulley.

The shale after being dried is elevated to a storage bin holding 4,000 tons. The shale at this point has the following screen analysis:

Original from THE OHIO STATE UNIVERSITY

Screen size passed	Per cent
1 inch	100.0
¾ do	98.7
⅜ do	94.9
4 mesh	87.2
8 do	73.3
16 do	55.7
30 do	34.2
50 do	22.0
100 do	11.6

From storage the shale is drawn into a tunnel, conveyed by a 12-inch screw conveyor to a bucket elevator, and lifted to a small bin. It is next slightly pulverized in a small ball mill driven by a 15-hp., 750-r.p.m. motor. This ball mill was originally put in to catch the spikes and track bolts coming with the shale from the quarry. The mill contains about 400 pounds of 1 and 2 inch balls that have been worn down in the rock ball mills. From this ball mill the shale is conveyed to the scale, where it is weighed and added to the limestone. The following is the screen analysis of the shale from the ball mill:

Screen size passed	Per cent
¾ inch	100.0
⅜ do	97.3
4 mesh	89.5
8 do	75.7
16 do	59.4
30 do	34.4
50 do	26.5
100 do	19.3

WAGE SCALE

All wages are paid on an hourly basis, except to the foreman and shovel engineer, who are paid by the month, and to the drillers, who are paid for the footage drilled. The normal wage scale is as follows:

Position	Number of men	Wage
Foreman	1	$250.00 per month
Engineer (shovel)	1	200.00 do
Engineer (locomotive)	2	.55 per hour
Craneman	1	.55 do
Fireman	3	.375 do
Brakeman	2	.35 do
Track foreman	1	.425 do
Driller	2	.07 per foot
Car repairman	1	.55 per hour
Car repairman	1	.50 do
Laborer	15	.325 do

SAFETY ORGANIZATION

The "Safety" idea has been so throughly instilled into the men that there has not been a lost-time accident in the quarry since November, 1927. The quarry foreman is on a committee with the other foremen from the mill, who are compelled to attend every safety meeting. Two general meetings a month are held and at least one-half of the quarry men attend each meeting, thereby making each quarry man attend one safety meeting a month.

During the year 1928 the plant was divided into seven safety groups, as follows:

1 - Quarry.
2 - Raw-grinding department.
3 - Machine shop and laboratory.
4 - Yard gang and finishing department.
5 - Packing department.
6 - Electricians, stockroom and office men.
7 - Power house and kiln room.

Each of these groups comprised from 25 to 35 men. With all of these groups trying to avoid accidents, the plant ran during 1928 and 1929 without a lost-time accident.

At the semimonthly meetings, which have been entirely in charge of the author, a monthly bulletin, "Significant Accidents," of the Portland Cement Association is read. Every accident reported that could have occurred at our plant is thoroughly discussed, in order to benefit from the experience of other plants. Weekly inspection reports of the plant are read, and recommendations are discussed and approved if thought practical. A safety engineer from the insurance company visits one of the meetings each month, giving us a safety talk and his experience in other industries.

The accident record of this plant since 1927 is as follows:

Accident record, 1927-29

Year	Severity rate	Number lost-time accidents	Days lost	Total man-hours worked
1927	0.203	12	167	823,119
1928	.000	0	0	798,431
1929	.000	0	0	799,355

During the Christmas holidays of 1928 and 1929, the company, to show its appreciation of the cooperation of the men in this safety work, gave each man a check for 10 dollars, and on the fourth of July of each year an old-fashioned Southern barbecue was given to the men and their families.

In the fall of 1929 about 75 men were given the first-aid course of the U. S. Bureau of Mines. Since then much time has been given to this instruction in order to teach every man in our organization the benefits derived from first-aid training.

We feel proud of our safety organization, as it has enabled us to complete two successive years without a lost-time accident, thereby making us the possessors of a Portland-Cement Association trophy.

ORGANIZATION

Figure 6 shows the organization chart for the entire plant.

Table 1.- Summary of costs

Trinity Portland Cement Co., Dallas, Tex.
Period: January, to December 31, 1929.

Total material loaded during period: Overburden (included with stone).
Stone, 295,768 tons (2,000 lbs.).

Operating costs per dry-ton of stone mined

	1	2	3	4	5	6	7	8
	Labor	Supervision	Air drills steel	Power cost	Fuel cost	Explosives cost	Other supplies	Total
Mining:								
Drilling	$0.0103	-	$0.0011	-	-	-	-	$0.0114
Blasting	.0030	-	-	-	-	$0.0433	-	.0463
Loading	.0472	$0.0051	-	-	$0.0357	-	$0.0159	.1039
Transportation	.0902	-	-	-	.0244	-	.0135	.1281
Miscellaneous	.0184	.0050	-	-	-	-	.0105	.0339
Crushing	.0166	-	-	-	-	-	-	.0166
Grinding	.1422	-	-	$0.1144	-	-	-	.2566
Elevating	.0027	-	-	-	-	-	.0015	.0042
Conveying	.0021	-	-	-	-	-	.0005	.0026
Drying	.0096	-	-	-	.1622	-	-	.1718
Miscellaneous plant	.0507	-	-	-	-	-	.0719	.1226
Total operating costs	0.3930	0.0101	0.0011	0.1144	0.2223	0.0433	0.1138	0.8980

Overhead and miscellaneous costs per ton are as follows: Depreciation, $0.03; depletion, $0.01; taxes, $0.01; insurance, $0.01, and miscellaneous overhead, $0.02, which together with operating costs give a total cost of $0.978 per dry-ton of stone mined.

Table 2.- Summary of costs in units of labor, power, and supplies

Period: January 1 to December 31, 1929.

Material loaded during period: Stone, 295,768 tons.
Weight per cubic yard, loose measure, 2025 pounds.

	Mining	Crushing	Total
A. Labor (man-hours per ton):			
Drilling	0.0197	-	0.0197
Blasting	.0080	-	.0080
Loading	.0840	-	.0840
Haulage	.2090	-	.2090
Miscellaneous	.0480	-	.0480
Supervision	.0120	-	.0120
Total Labor	.3807	-	.3807
Average tons per man-shift	-	-	26.27
Labor, per cent of total operating cost	-	-	43.76
B. Power and supplies:			
Explosives (lb. per ton)	-	-	.2513
Total power (kw.h. per ton)	-	-	29.60
Shovels	-	-	.0000
Locomotives	-	-	.0000
Drills	.0800	-	.0800
Crushing	-	2.2330	2.2330
Grinding	-	22.8482	22.8482
Elevating	-	1.4544	1.4544
Conveying	-	1.4544	1.4544
Drying	-	.9467	.9467
Shops	-	.2780	.2780
Lighting	-	.3053	.3053
Fuel:			
Gas for drying rock and shale (cu. ft. per ton)	-	-	926
Coal for shovels and locomotives (lbs. per ton)	-	-	18
Supplies and power, per cent of total operating cost	-	-	55.11

Table 3.- Detailed average shovel costs, direct operation

Period: January 1 to December 31, 1929.
Stone loaded; 295,768 tons.
No. 70 Marion shovel; 2½-yard dipper.

	Cost of stone	
Shovel operation	Total	Per ton
Engineers	$ 2,400.00	$0.0081
Cranemen	1,818.85	.0061
Firemen	1,240.12	.0042
Foremen	3,000.00	.0101
Pitmen	4,103.45	.0138
Other operating labor	1,884.85	.0064
Total operating labor	14,447.27	.0487
Fuel or power	10,568.67	.0357
Grease and lubricants	285.06	.0010
Other operating supplies	163.26	.0006
Total supplies	11,016.99	.0373
Shovel-repair labor	1,426.37	.0048
Shop labor	1,265.28	.0043
Repair supplies	2,593.45	.0088
Total repairs	5,285.10	.0179
Total shovel operation	30,749.36	.1039

Table 4.- Detailed summary costs - direct operation

Period: January 1 to December 31, 1929.

	Cost of stone	
	Total	Per ton
Total all shovels	$30,749.36	$0.1039
Drilling:		
Operating labor	2,703.82	.0090
Operating supplies	313.27	.0011
Repair labor	167.46	.0006
Repair supplies	194.04	.0007
Total drilling	3,378.79	.0114
Blasting:		
Labor	878.00	.0030
Explosives	12,794.00	.0433
Total blasting	13,672.00	.0463
Haulage:		
Locomotives	12,804.22	.0433
Cars	6,700.60	.0226
Track Maintenance	18,390.19	.0622
Total haulage	37,895.01	.1281
General charges	10,018.21	.0339
Grand total	95,713.37	.3236

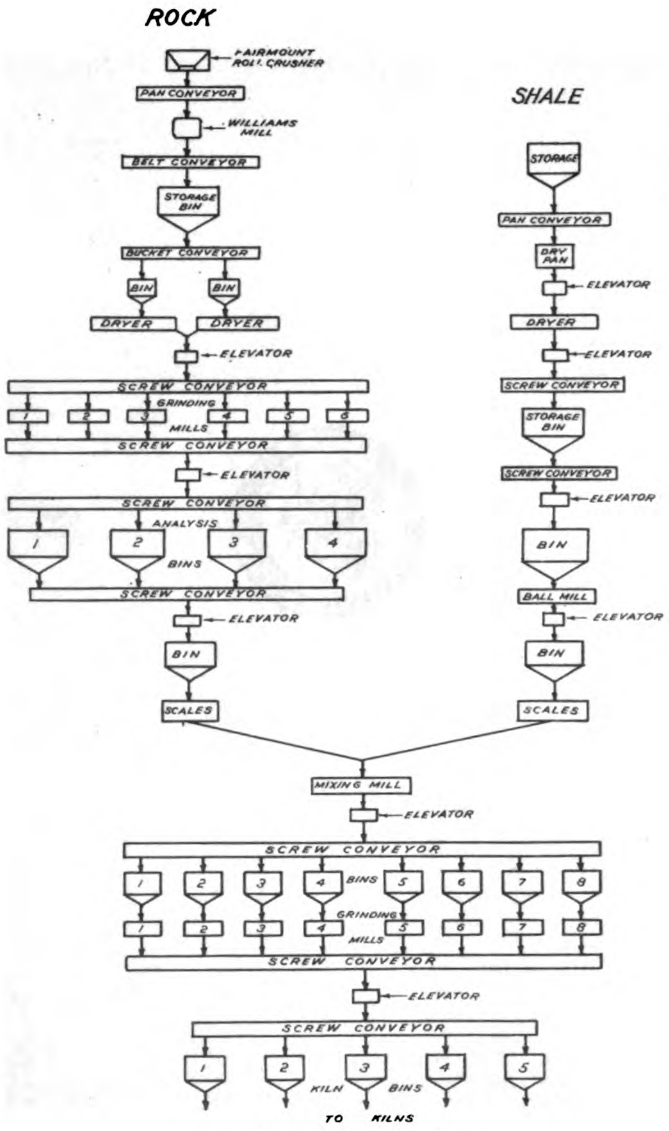

Figure 4.- Flow sheet

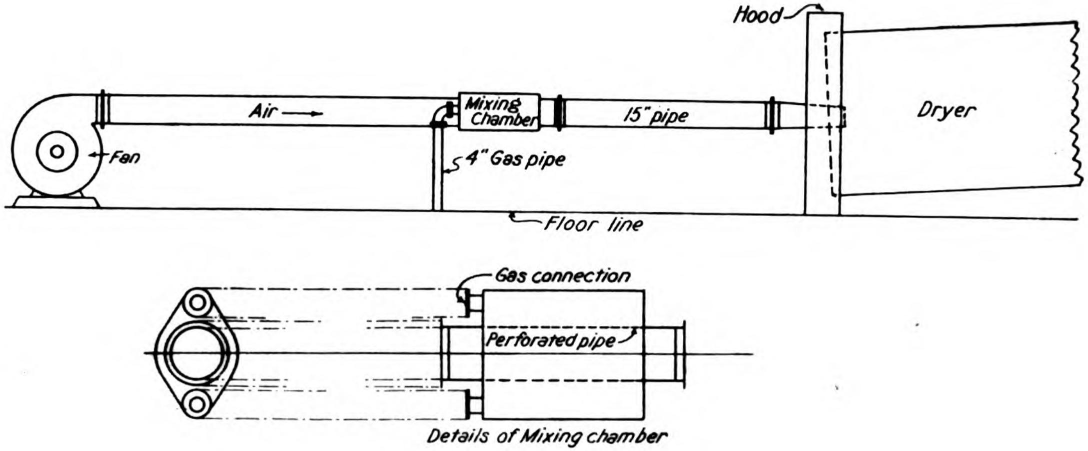

Figure 5.- Gas burning apparatus

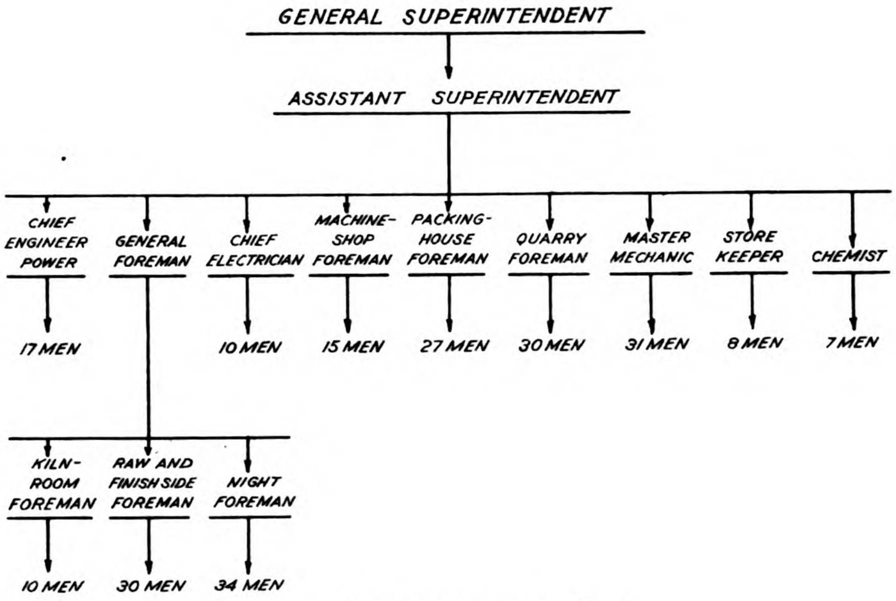

Figure 6.-Organization Chart

Original from THE OHIO STATE UNIVERSITY